

PHYSOR 2004 Luncheon speech

“An historical perspective of Experimental Reactor Physics” by M.SALVATOIRES

It is rather impressive that this conference can gather every two years such an outstanding audience. Since 1990 this conference has taken the denomination “PHYSOR”, which was invented for the 1990 edition in Marseille, the first outside the US. Since then, PHYSOR has travelled to Asia and Europe, besides the US of course.

Today we are back in Chicago, the historical landmark for nuclear technology and for reactor physics.

It is rather customary in these occasions to make critical reviews, or to risk predictions for new directions. Serious matters. Not well suited for a luncheon speech. Better to be entertaining. If you can or know how to be entertaining. Not really my “cup of tea”.

Fortunately, I was suggested to talk on reactor physics and experiments, one of my favourite topics. And I hope not to destroy the pleasure of your lunch (**figure**).

As Eugene Wigner pointed out, of all modern technologies, nuclear reactor technology is unique in having sprung up full blown almost overnight. Only four years separate the date of discovery of fission and the date of the first chain reaction. And nine years later in 1951, electricity was first produced from fission at the Experimental Breeder Reactor I in Idaho.

These were the years of excitement : the founders of reactor physics were Nobel Prize winners : Fermi, Wigner, even Feynman , to name only a few.

Neutron transport theory and radiative transfer in stellar atmospheres were found to be based on the same equations, at least in the case of constant cross-sections for neutrons, and in the case of grey atmosphere with unpolarized light for stellar environment. And the name of Chandrasekar comes to mind.

Theoretical developments were characterized by what Wigner himself one time called “the unreasonable effectiveness of mathematics”. An age of elegance in reactor theory and models, even if Einstein once warned scientists to leave elegance to tailors!

A triumph for theoretical reactor physics. But, be careful with theoreticians ...

And here, allow me a short diversion to quote a once-famous joke about the first day in Heaven of W. Pauli, the theoretician “par excellence”. At the pearly gate, Saint Peter says :

“Pauli, God wants to meet you right away”, and shows him the proper direction. At God’s palace, the Deity says :

“Pauli, you have been a good man, and I want to reward you in some way. Ask me any question you like

“Without hesitation Pauli says : “Explain the fine structure constant”.

So God goes to the blackboard and starts writing, and Pauli listens in pleasure. But after two minutes Pauli stops smiling. After five minutes, he is shaking his head - and suddenly he is up on his feet, hissing “Das ist ganz falsch ! That’s completely wrong !”

In the same mood, I like to remember a letter that Rutherford, with his sound British predilection for experiments and sense of humour, sent to Fermi, who after establishing the theory of beta decay, was feverishly bombarding nuclei of all elements with neutrons : “I congratulate you, Rutherford writes to Fermi, on your successful escape from the sphere of theoretical physics ! You seem to have struck a good line to start with. You may be interested to hear that prof. Dirac also is doing some experiments. This seems to be a good augury for the future of theoretical physics.

Needless to say, experiments did not form a major part of Dirac’s oeuvre. Fermi on the contrary, is the last twentieth-century physicist to make great contributions to both theory and experiments.

And which experiments !

The beginning of the nuclear technology era is exactly the Fermi experiment (**figure**), which I like to show here as illustrated with touching simplicity by Raymond Murray.

In the fifties creative experiments were conceived all over the world. It is sufficient to have a look to the first issue of Nuclear Science and Engineering (**figure**), to be convinced of the spectacular role of experiments at that time.

It is the age of exponential experiments, performed by hundreds to validate lattice theory.

“Danger” coefficient experiments, producing spectacular results as the ones shown here (**figure**) obtained at ZEPHYR in Great Britain, to assess absorption cross-sections.

It was the time of the invention of the oscillation experiments, a giant step forward for the same objective.

It was the time of the first measurement of the dispersion of neutron emission from fission, by Feynman and co-workers in 1956.

These experiments were the precursors of the most powerful modern experiments, like the integral experiments to validate design codes using actual power reactor assemblies (**figure**),

or oscillation experiments still performed today (for example at MINERVE, **figure**) with high accuracy to validate the so-called “burn-up” credit or the MOX fuel performance.

And once can consider the Feynman experiments as precursors of the noise measurements of reactivity as performed at present.

In the seventies and eighties, critical experiments are performed in all leading R and D laboratories in support of Fast Reactor Development. The focus was on high accuracy measurements, and powerful experimental techniques were developed at that time. With the help of such experiments and techniques, the critical mass of SUPER-PHENIX was predicted with a discrepancy of little more of one subassembly (out of 350).

We have seen in the last few years a somewhat less exciting environment. A “common sense” age. Fast reactor deployment has been delayed, very few new power plants.

As far as operating reactors, the keyword is “let them run smoothly and more effectively”. Less space is left to creative new experiments. Fair enough.

However, I personally feel uncomfortable reading, once more, the warnings formulated by E. Wigner : There has been probably less appreciation of the need to develop further the “scholarly tradition” toward the highest approximation to the truth. All too often what is

commonly known does not represent the highest approximation to the truth ; and what is the most penetrating and nearest approximation to the truth is often not commonly known.

It has a bit forgotten that in all really creative thinking in reactor design, a working knowledge of nuclear reaction theory is required.

Moreover, there is a deplorable trend in reactor studies, the tendency to substitute a “code” for a theory.

Believe it or not, I was quoting from the preface of “The Physical Theory of Neutron Chain Reactors”, by Alvin Weinberg and E. Wigner, published in 1958 !

I will add my personal feeling that we have been used to trust “gedanken” experiments or to believe that “numerical” experiments is all what we need. In a sense, the end of the experimental world of reactor physics. The only active field seems to be the one of Criticality-Safety.

However, this conference should confirm that, despite these trends, there are signs that we are “back to the excitement” !

In fact the powerful renewal of interest for waste management and the back-end of the fuel cycle, the launching and consolidation of the GENERATION-IV initiative and even the more reasonable attitude towards systems like Accelerator Driven Systems (**figure**), (for which a limited but better defined field of potential application has been found) : all these domains clearly point out new needs for better basic nuclear data, rigorously validated calculational tools, and then new creative experiments.

I firmly believe that, if we are back to develop innovative systems, both reactors and associated fuel cycles, we will feel soon the need of appropriate experiments. And probably we will feel a cruel lack of appropriate facilities !

In fact, we already feel the difficulty to answer utility requirement to reduce margins in the case of extended burn-ups for MOX fuelled LWRs.

By the way, the field of very high burn-ups is clearly a field of still important needs for experiments. The use of real irradiated fuel from power reactors in critical facilities is already envisaged by some skilful experimental teams.

Before talking of the potential needs related to GEN-IV systems, let me make a remark on GEN-III. In fact we all hope that this year will be the year of the launching of EPRs in Europe. Even if we can expect a limited need for specific new experiments, we have to keep in mind that this is so, because relevant physics experiments have been performed already in recent years and they give an extended confidence on the performance of calculation tools, in particular for MOX-loaded LWRs.

Turning now to the future, the clear indication of Fuel Cycle studies in the frame of GEN-IV, is in the direction of integrated fuel cycles, where spent fuel constituents are multi-recycled all together.

This approach will stress the need for a widely improved experimental knowledge of the decay heat, of neutron sources at fuel fabrication, of the intrinsic neutron sources at reactor shutdown, the need for better delayed neutron data. In fact, the presence in the fuel of non-negligible amount of Minor Actinides will be a new and challenging physics characteristics for both the reactors and the fuel cycle.

A clever use of power reactors can be imagined for performing new types of irradiation experiments (**figure**), and I believe the Accelerator Mass Spectrometry (**figure**) can help to investigate the build-up of very high mass nuclides of relevance for future fuel cycles.

We do not expect to discover a new physics for Gas cooled Fast Reactors or VHTR's, but the presence of new materials and specific problems related to the presence for example of reflectors and void channels, will need experimental research using the most sophisticated experimental techniques to reduce design margins and uncertainties.

And we will not have a close look to the icy-moons of Jupiter without some good critical experiment on Earth!

In summary, there is and there will be strong needs for experimental reactor physics.

In this respect, are we preparing the future ?

International initiatives, like GENERATION-IV, or the foreseen synergy at least between the US and Europe of initiatives and programs in the field of advanced fuel cycles, show the way

towards joint experimental programs to be performed at centres of excellence like Cadarache in France or PROTEUS in Switzerland, or on the Russian facilities at Obninsk.

International experimental programs can foster the training of a new generation of experimental physicists in absence of which, our future will be gloom.

If we have a vision, there is hope for further progress, even if we have not worked out all the details :

“If you can look into the seeds of time, and say which grain will grow and which will not, speak then to me”. (figure)

Thank you for your attention.